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E S S A Y

ON THE

SUBJECTS OF CHEMISTRY,

AND THEIR

GENERAL DIVISION.

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AN
ESSAY
ON THE
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ALL terrestrial existencies may, in one view or other, be considered as the subjects of Chemistry: they are usually divided into three distinct classes, called the three kingdoms of nature; the first includes Minerals, the second Vegetables, the third Animals. Natural History, in an extended sense, comprehends the knowledge of whatever relates to terrestrial existencies, exclusive of the moral actions of man, which constitute the basis of civil history; and of the

the physical actions of bodies one upon another, which are the foundation of natural philosophy.

Mineralogy is that part of natural history which treats of whatever is found upon the surface, or dug out of the bowels of the earth, except animal and vegetable substances: some have excepted water also, and denominated that branch of science which explains the properties of water, Hydrology. And indeed, many Chemists have thought proper to consider water, as not appertaining to any of the three kingdoms of nature; but it hath no better right to be distinguished from a solid, elastic, diaphanous mineral, than a melted metal hath to be distinguished from the same metal when concreted into a solid form: in their different states of fluidity and solidity they will have different properties; but should not, from such accidental changes as are effected by minute variations of heat, be referred to different classes: had water been called melted ice, no one would have scrupled to consider it as belonging to the mineral kingdom.

The reducing quicksilver into a solid, malleable metal, by a due degree of cold,
was

was an important discovery in physics: we learn from thence to consider all fluid bodies such as water, oils, spirits, æthers, and probably the air itself, as convertible into solids without the introduction of any frigorific particles, but simply by a diminution of heat; and all solid bodies, as convertible into fluids, without suffering any other change in their constitution, except what arises from the volatilization of such of their principles, as cannot sustain the degree of heat requisite to render the rest fluid.

Mineralogy is principally employed in arranging similar bodies under the same, and dissimilar bodies under different denominations. It judges of similarity two ways; either from the similarity of the external appearance, or from the similarity of the internal constitution. The knowledge of the similarity of the internal constitution of bodies is acquired, chiefly by regarding the changes produced in them by the action of fire, or the action of menstruums; that of the external appearance by regarding the colour, configuration of the superficial parts, consistency, and weight. From the knowledge of the constituent parts of bodies is derived their œco-

nomical application, their use in medicine, agriculture, metallurgy, and other arts: from the similarity of the external appearance, is derived a suspicion concerning the identity of the internal constitution; a suspicion, serviceable in suggesting conjectures to philosophic minds, relative to the generation, transmutation, and destruction of natural bodies.

Most Mineralists have contented themselves with classing the various species of Fossils according to their most obvious qualities, and have thereby referred things very heterogeneous to the same genus. In the animal and vegetable kingdoms, the external appearance is of essential use in helping us to reduce them into genera and species: indeed, when from a resemblance in one or two particular parts of a plant or an animal; as from the figure of the leaves, or the number of stamina; from the shape of the hoof, or the number of teeth, we venture to arrange them under the same general denomination, great confusion will arise, if we suppose that general denomination, to infer a resemblance more extensive than the idea from whence it was derived: nature often admitting a similarity in some particulars

culars coexistent with the greatest dissimilarity in others: it is not probable however, that Linnæus in classing the productions of nature ever entertained such a supposition, and he seems therefore to have been uncandidly censured. But when the whole external appearance of a plant, or an animal is taken into consideration, it is far easier to refer it to a particular class, than from a chemical enquiry into its internal constitution. In fact, the internal constitution depends, in a great measure, upon the same principle from which the external figure is formed. From the configuration of the vascular system, through which nutrition is conveyed to every part of a plant or an animal, is derived the external figure; and from the same configuration the internal properties seem to arise: for plants become acescent or alcalescent, sweet or bitter, poisonous or salubrious according to their different natures, tho' they be planted in the same soil, and fed with the same food, that being changed and elaborated, by processes which we can neither understand nor imitate, into different fluids by the different organizations; and, I had almost said, digestive powers of different plants.

plants. The case is quite otherwise with respect to minerals, the external appearances conveying to us little real knowledge; they may be the same in different bodies, or different in the same body.

Sir Isaac Newton has proved, that the colours of natural bodies depend upon the thickness and density of the component parts, and consequently that minute changes in either of these qualities will make very considerable changes in the colour: this Philosophy is confirmed by, and serves at the same time to explain many appearances in Chemistry. Crystals of quicksilver in Aqua Fortis are white, yellow, or red, according to the degree of heat to which they have been exposed; whilst on the other hand, the same quicksilver corroded into a saline mass by Oil of Vitriol, remains perfectly white in all degrees of heat, but by the affusion of water is changed at once into a vivid yellow, which is of different shades according as the water is hot or cold, or as the Mass hath been more or less freed from its adhering acid by calcination. Iron and lead, and most other metals undergo similar changes of colour from calcination and precipitation, so that nothing
seems

seems more uncertain than the classing of bodies from a respect to their colour. This uncertainty of colour, according as the heat is various, is much felt and complained of by Enamellers, and the makers of artificial gems.

The configuration also of the superficial parts is a very uncertain characteristic of the specific nature of a Mineral: Metallurgists are sensible of this, they are obliged in many cases to have recourse to fire, before they can pronounce concerning the metal contained in an ore, whether it be lead or silver, iron or antimony. We have a notable instance of this uncertainty in what is called the stellated regulus of antimony; the crystallization on the surface resembling the radiations of a star, the scales of a fish, branches of trees, fibrillæ of feathers and other matters, according to certain diversities of circumstances attending the process. I do not deny but that a definite degree of liquidity in the Regulus and Scoria, a definite quantity and quality of the Scoria, and a proper precision in some other matters, would ever produce a definite arrangement of the superficial parts; but it is certain that a small variation

tion in any of these, will make a great change in the outward and inward appearance of the Regulus, without affecting in any sensible manner its internal composition. Another instance will shew the imperfection of this external method of classification still more obviously: In several portions of water let there be dissolved nitre, sea salt, alum, borax, sugar, saccharum saturni, corrosive sublimate, &c. or any combinations of these salts, the several solutions will still be equally colourless and transparent, and by a sufficient degree of cold suddenly applied would be concreted into solid bodies, not to be distinguished from one another by their colours, figures, consistencies, nor (so the experiment might be managed) specific gravities.

By these instances from Chemistry we can apprehend, how there may be a perfect similarity in the external appearances of bodies, when their internal constitutions are wholly different, and a dissimilarity, when they are wholly the same. The Minerals produced by nature are analogous to these of art, and hence we may infer the great confusion and obscurity which must necessarily attend a natural History of Minerals,

nerals, when it is founded only on the external appearance.

Sensible at last of this imperfection, the composers of systems of Mineralogy have availed themselves of the assistance of Chemistry, and have endeavoured to class Minerals according to their internal properties. This method is perfect in its kind; and in particular instances deserves greater or less attention, according as the analysis of Minerals is more or less complete: in many cases however it is too general and abstracted for common use. For instance, all earths or stones which by a certain assignable degree of heat, and with a certain quantity of saline additions, are convertible into glass, may be called vitrifiable earths; all earths or stones which in the same degree of heat, and with the same quantity of saline additions, or without them, are not convertible into glass, but into quick lime, may be called calcareous earths; and all earths or stones which under similar circumstances remain unaltered in their properties, may, with respect to the other two kinds, be called refractory earths. This is all we can learn from Chemistry relative to the comparative na-

tures of earths, when exposed to a given degree of heat; and hence fish shells, chalk, limestones, and marbles would be included in the same class: but to answer the purposes of common life, it will be necessary to make a more particular division of them, which can only be done after the generic idea hath been established, by contemplating the external appearances; in which view the colour or figure, or both together, would be principally respected; as in fact we see they are in the distinction of the Italian Antico's, as Marmore Nero, Giallo, Rosso di san guisto; di Fiorenza, Pæfino; Alberino di Monte Gallicano, &c. all of which are convertible into quicklime, but from their different colours, superficial contextures, and capabilities of receiving different polishes, they have become of different values in a commercial light, and therefore are not improperly distinguished in a system of Mineralogy. In like manner, tho' a chemical examination by fire would probably refer diamonds, emeralds, rubies, topazes, and other stones generally denominated precious, to the class of flints; yet since men have annexed a fanciful value to these pebbles

bles from their pellucidity, colour, hardness, and other external attributes, it would be a great defect in a mineral system not to have them particularly specified and described.

But to discriminate common limestones, or common flints into different species, from a minute variation of the figure or the colour; to class pyrites, or combinations of sulphur and iron, under the specific denominations of spherical, hemispherical, pyramidal, cubical, &c.; to divide, as is usually done, the ores of the same metallic substance into a great variety of kinds, when an assay will give no difference either in the quantity or quality of the metal contained in them, or of the matter by which they are mineralised, seems to be a *multiplicatio entium præter necessitatem*, and tends rather to obscure and circumscribe, than to elucidate and extend our knowledge of nature.

Upon the whole, the great outlines and general divisions of mineral productions may most usefully be made from a chemical investigation of their constituent parts, and where it is expedient for commercial purposes to be more particular, an atten-

tion to the external appearance will be proper for that end. A Mineralist who considers gypseous alabasters, plaster stone, lamellated gypsums, rhomboidal selinites, spatum Bononienſe, and a great many other bodies as proper to be distinguished from one another, and who is able to ascribe any particular body to its proper species from considering its external appearance, is possessed of a particular kind and degree of knowledge: He who besides being acquainted with the external appearances, is able to prove that all these different bodies are composed of a calcareous earth, united to the vitriolic acid; and thus make several species of things coalesce together, and unite, as it were, under one general conception, hath a knowledge of these bodies different in kind, and superior in degree. By this sort of knowledge the memory is much relieved, and the mind, ever grasping after universal truths, is gratified with the acquisition of general ideas. These two very different kinds of knowledge belong to every part of Mineralogy, in different views each of them is of indispensable use, and a perfect system of Mineralogy should include them both.

If

If it be asked what are the discriminative characteristics of Minerals, Vegetables, and Animals as opposed to one another, I plainly answer that I do not know any either from natural History or Chemistry which can wholly be relied on.

Systematic distinctions, and specific divisions of things, are useful in enlarging the comprehension of the mind; by methodizing the objects they seem to extend the boundaries of knowledge: but having no real foundation in nature, they should not be depended on too far; they often perplex or impede the progress of a curious enquirer. This prepossession in favour of systematic arrangements, operates more forcibly upon us as the ideas to which it is usually annexed become the more abstracted. The strongest analogies are overlooked, the plainest reasonings thought fallacious, and decisive experiments inconclusive, when their tendency is to subvert a distinction, of which we had wrongly supposed nature herself the author. Every one thinks that he knows what an animal is, and how it is contradistinguished from a vegetable, and would be offended at having his knowledge questioned thereupon.

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A dog or a horse he is truly persuaded, are beings as clearly distinguished from an herb or a tree, as light is from darkness; yet as in these, so in the productions of nature, the transition from one to the other is effected by imperceptible gradations.

The loco-motive powers which appertain to most animals, whether they proceed from the Cartesian mechanism, or from sensation, are so manifest in quadrupeds, birds, fishes, and insects, that in our first and superficial enquiries into nature, we are apt to consider the possession or want of these powers, as making a decisive and essential difference between animal and vegetable bodies; and it is not without a certain degree of regret, as it were, that we find ourselves obliged to predicate animality concerning a great variety of beings, which are destitute of every power of progressive motion. If at the same time we happen to have entertained some preconceived opinions, no matter whence they have been derived, concerning the usual shapes of animals, (tho' they are far more different from one another than some of them are from vegetables) our repugnancy to the admitting a being of the outward

ward form of a shrub, into the class of animals, is much increased. Hence have proceeded most of the objections which have been made to the fine discoveries of Peyssonel, Jussieu, Ellis and others, relative to the animal nature of corals, madrepores, millepores, corallines, sponges, and a numerous tribe of bodies which the very ingenious labours of Marfigli had formerly removed from the mineral kingdom, where they had been placed by Woodward and other Mineralists, and allotted to that of vegetables.

If rejecting spontaneous motion and figure as very inadequate tests of animality, we adopt perception in their stead; no doubt, he would be esteemed a visionary in Philosophy who should extend that faculty to vegetables; and yet there are several chemical, physical, and metaphysical reasons which seem to render the supposition not altogether indefensible.

The greater the quantity of perception existing in the universal system of creation, the greater is the quantity of happiness produced; and the greater the quantity of happiness produced, the greater is the goodness of the Deity in the estimation of Beings

Beings with our capacities. The latter part of this proposition needs no proof; and the former is liable but to one objection, and that grounded upon a false supposition. If, it may be urged, all the species of percipient beings be not accommodated with objects congruous to their faculties of perception, and productive of more pleasure than pain to the whole species taken collectively, then the animation of that matter of which they consist is an introduction of evil, and no test of benevolence. This may be granted; but in all the species of beings which come within the observation of our senses, the supposition of their not being furnished with objects suited to their wellbeing is evidently not true, and therefore ought, from analogy, to be rejected with reference to such as by their magnitude, their minuteness, or their dullness of perception escape our examination.

That animals should feed one upon another, is a law of nature full of wisdom and goodness, life and happiness being indefinitely multiplied thereby. For a given quantity of what are called vegetables, annually produced upon a globe of a given diameter,

diameter, being sufficient but for the support of a given number of herbaceous animals, whose place in the universe not admitting their immortality, it hath been wisely contrived that their bodies, which from their structure must perish, should in ceasing to live, become the instruments of supporting life in beings, which could not by any other means have had an existence, at least upon this globe; and of the other parts of the universe we know nothing except from analogy, and from that we must conclude that the $\tau\omicron\ \pi\alpha\nu$, be it finite or infinite, is as full of life as this particular part with which we are connected. Nay, animated matter, containing as it were the concentrated virtue of many vegetables, serves for the support of life, and the consequent communication of happiness in a far more ample manner than vegetables themselves; animal substances in equal weights furnishing more nutriment than vegetable. It is by death, a seeming imperfection in his workmanship, that the Deity preserves vegetable life, supports the animal kingdom, daily regulates and renews the œconomy of nature, and continues this wonderful system of things in

full youth and vigour, nor interrupted by disease, nor enfeebled by old age.

No objection therefore to the animality of vegetables can be brought from any considerations respecting their daily destruction; for the destruction of animals by other animals, the bellum omnium in omnia, is an universal law of nature, derived from the same benevolence to which we attribute creation itself. If then every part of the vegetable kingdom hath a degree of perceptivity, however small, there will be a gain of happiness to the whole system, the aggregate may be of a value not to be overlooked by him, to whom the existence of all things is equally possible, and from whom all created existences are equally distant in perfection.

Wherever there is a vascular system, containing a moving nutritive succus, there is life; and wherever there is life there may be, for ought we can prove to the contrary, a more or less acute perception, a greater or less capacity for the reception of happiness: the quantity, indeed, of which after we have descended below a certain degree of sensibility, will, (according to our method of estimating things, which is ever
partial

partial and relative to ourselves) be small in each individual; yet is the existence of it in the nature of things possible, from the analogy of nature probable: and who can tell whether in a system of nature, confessedly contrived for the production of the greatest possible good, it may not also be necessary?

It should be well weighed by the Metaphysicians, whether they can exclude vegetables from the possession of the faculty of perception, by any other than comparative arguments; and whether the same kind of comparative reasoning will not equally exclude from animality those animals which are provided with the fewest and the obtusest senses, when compared with such as are furnished with the most and the acuteest. The perception of a man (tho' it may be doubted whether there are not several animals which have all the senses more acute) seems to be indefinitely greater when compared with that of corallines, sea-pens, and oysters, than the perception of these, which are allowed to be animals, doth when compared with the signs of perception manifested by a variety of what are called vegetables. Spunges

open and shut their mamillæ, corals and sea-pens protrude or draw back their suckers, shell-fish open or keep close their shells in search of food or avoidance of injury; it is from these and similar muscular motions that we judge the beings to which they belong to have perception, that is, to be animals. Now in the vegetable kingdom, we may observe the muscular motions of many plants to be, to the full, as definite and distinguishable as those of the class of animals just mentioned. The plants called *Heliotropæ* turn daily round with the sun; by constantly presenting their surfaces to that luminary, they seem as desirous of absorbing a nutriment from its rays, as a bed of muscles doth from the water, by opening their shells upon the afflux of the tide. The *Flores Solares* are as uniform in their opening and shutting as animals are in their times of feeding and digesting; some in these motions do not observe the seasons of the year, but expand and shut up their flowers at the same hour in all seasons; others, like a variety of insects which appear, or not, according to the heat of the weather or climate, open later in the day, or do not open at all, when they

they are removed from a southern to a more northern latitude. Trefoil, woodforrel, mountain ebony, wild fenna, the African marigold, &c. are so regular in folding up their leaves before rainy weather, that they seem to have a kind of instinct or foresight similar to that of ants; which however deserts many of them as soon as they have propagated their kind, by shedding their pollen. Young trees, in a thick forest, are found to incline themselves towards that part through which the light penetrates, as plants are observed to do in a darkened chamber towards a stream of light let in through an orifice, and as the ears of corn do towards the south. The roots of plants are known to turn away with a kind of abhorrence from whatever they meet with which is hurtful to them, and to desert their ordinary direction, and to tend with a kind of natural and irresistible impulse toward collections of water placed within their reach: many plants experience convulsions of their stamina upon being slightly touched. Whatever can produce any effect upon an animal organ, as the impact of external bodies, heat and cold, the vapour of burning sulphur,
of

of volatile alcali, want of air, &c. are found to act also upon the plants called sensitive. But not to insist upon any more instances, the muscular motions of the *Dionæa Muscipula* lately brought into Europe from America, seem far superior in quickness to those of a variety of animals. Now to refer the muscular motions of shell fish, and zoophytes, to an internal principle of volition, to make them indicative of the perceptivity of the being; and to attribute the more notable ones of vegetables, to certain mechanical dilatations, and contractions of parts occasioned by external impulse, is to err against that rule of philosophizing which assigns the same causes for effects of the same kind. The motions in both cases are equally accommodated to the preservation of the being to which they belong, are equally distinct and uniform, and should be equally derived from mechanism, or equally admitted as criterions of perception.

I am sensible that these and other similar motions of vegetables, may by some be considered as analogous to the automatic or involuntary motions of animals; but as it is not yet determined amongst the Physiologists, whether the motion of the heart,
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the peristaltic motion of the bowels, the contractions observable upon external impulse in the muscles of animals deprived of their heads and hearts, be attributable to an irritability unaccompanied with perceptivity, or to an uneasy sensation, there seems to be no reason for entering into so obscure a disquisition; especially since irritability, if admitted as the cause of the motions of vegetables, must, a fortiori, be admitted as the cause of the less exquisite and discernible motions of beings universally referred to the animal kingdom.

Physical observations concerning the generation, nutrition, organization, life, health, sickness, and death of plants, help us as little towards the establishing a discriminative characteristic between them and animals, as metaphysical speculations relative to the quantity of happiness, or degrees of perceptivity.

The eastern practice of fecundating the female palm tree by shaking over it the dust of the male, which Herodotus mentions in his account of the country about Babylon, and of which Dr. Hasselquist in the year 1750 was an eye witness, was not unknown to Aristotle and Pliny: but the
Ancients

Ancients seem not to have carried the sexual system beyond that single instance, which was of so remarkable a kind that it was hardly possible for them to overlook it; at present there are few Botanists in Europe who do not admit its universality. It seems generally agreed, that a communication of sexes in order to produce their like belongs to vegetables as well as to animals. The disputes subsisting among the Anatomists concerning the manner in which conception is accomplished, whether every animal be produced ab ovo femellæ, or a vermiculo in femine maris, are exactly similar to those amongst Botanists concerning the manner in which the farina fœcundans contributes to the rendering the seed prolific: but however these doubts may be determined, they affect not the present enquiry, since it is allowed on all hands, that as the eggs of oviparous animals, tho' they arrive at their full magnitude, are incapable of being vivified by incubation, unless the female hath had commerce with the male: so the dates of female palm trees, and the fruits of other plants, tho' they ripen, and arrive at maturity, will not grow unless they have been
been

been fœcundated by the pollen of the male.

In like manner notwithstanding the diversity of opinion which hath long subsisted, and in a matter so little capable of being enlightened by experiment, probably ever will subsist, concerning the *modus agendi* by which nature elaborates the nutritive fluid, administers it to the fœtus in the womb, and produces an extension of parts; yet since a placenta and an umbilical chord are by all thought essential to the effecting these ends; and since the cotyledons of plants, which include the corculum or first principle of the future plant, with which they communicate by means of tubes branched out into infinite ramifications, are wholly analogous to the placenta and umbilical chord of animals, we have great reason to suppose that the embryo plant and the embryo animal are nourished and dilated in their dimensions after the same way. This analogy might be extended and confirmed by observing that the lobes, within which the fœcundated germ is placed, are by putrefaction converted into a milky fluid, well adapted as an aliment to the tender state of the plant.

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Expiration

Exspiration and inspiration, a kind of larynx and lungs, perspiration, imbibition, arteries, veins, lacteals, an organized body, and probably a circulating fluid appertain to vegetables as well as to animals. Life belongs alike to both kingdoms, and seems to depend upon the same principle in both: stop the motion of the fluids in an animal limb by a strong ligature, the limb mortifies beyond the ligature, and drops off; a branch of a tree under like circumstances, grows dry, and rots away. Health and sickness are only other terms for tendencies to prolong or to abridge the period of life, and therefore must belong to both vegetables and animals, as being both possessed of life. An east wind, in our climate, by its lack of moisture, is prejudicial to both; both are subject to be frost bitten, and to consequent mortifications; both languish in excessive heats; both experience extravasations of juices from repletion, and pinings from inanition; both can suffer amputation of limbs without being deprived of life, and in a similar manner both form a callus; both are liable to contracting diseases by infection; both are strengthened by air and motion: Alpine plants, and
such

such as are exposed to frequent agitation from winds, being far firmer and longer lived than those which grow in shady groves, or hot houses; both are incapable of assimilating to their proper substance all kinds of food; for fruits are found to taste of the soil, just as the urine, and milk, and flesh, and bones of animals, often give indications of the particular pabulum with which they have been fed: both die of old age, from excess of hunger or thirst, from external injuries, from intemperature of weather, or poisoned food.

Seeds of various kinds retain their vegetative powers for many years: the vivification of the ova, from which the insects occasioning the smut in corn, and the infusoria animalcula observable in water after the maceration of plants probably proceed, may be esteemed a similar phenomenon. It is not yet clearly decided amongst Naturalists, whether the seeds of mushrooms, of mucors, and of the whole class of Fungi be not in a tepid, humid matrix changed into vermicular animals, which lose in a little time their power of spontaneous motion, coalesce together, and grow up into these very singular plants:

the quickness of their increase, and the irresistible force with which the least mouldiness propagates itself, and destroys the texture of the bodies upon which it fixes, seem to point towards an animal nature.

Different vegetables require different soils, as different animals do different food for their support and well being: aquatics pine away in dry sandy grounds, and plants which love rocks and barren situations, where they imbibe their chief nutriment from the air, become diseased and putrid in rich bogs and swamps.

There are aquatic animals which become immoveable and lifeless when the rivulets in which they subsisted happen to be dried up, but which recover their life and loco-motive powers upon the descent of rain: in this circumstance they are analogous to the class of mosses among vegetables, which, tho' they appear to be dried up, and ready to crumble into dust during the heats of summer, yet recover their verdure and vegetable life in winter, or, upon being put into a humid soil.

Trembley, Bonnet, and Spallanzani have vastly amplified our views of nature; they have discovered to us divers species of animals,

animals, which may be cut into a variety of pieces without losing their animal life, each piece growing up into a perfect animal of the same kind: the multiplication of vegetables by the planting of branches, suckers, or joints of roots is a similar effect. The reproduction of the legs of craw-fish, lobsters, crabs, of the horns and heads of snails, legs of lizards, of the bony legs and tails of salamanders, when by accident or design they have been deprived of them; and the great difference in the time of the reproduction, according to the season of the year in which the limb is lost, are wonders in the animal kingdom, but wholly analogous to the repululation of trees after lopping.

All plants, except those of the classes *Monæcia* and *Diæcia*, are hermaphrodites; that is, they have the male and female organs of generation within the same empalement. Shell-fish, and such other animals as resemble vegetables in not being able to move far in search of mates, with which they might propagate their kind, are hermaphrodites also: Reaumur hath proved that vine fretters do not want an union of sexes for the multiplication of their kind,

From

From the conjunction of animals of different species are produced hybrides, which in many cases cannot propagate: Botanists have tried the experiment, and by fœcundating female flowers with the male dust of another species, have produced hybridous plants, of an intermediate shape, the seeds of which are barren and effete.

Trees shed their leaves as birds do their feathers, and hirsute animals their hair. At particular seasons the juices of vegetables move with fullness and vigour; at others they are less plentiful, and seem to stagnate; and in this they resemble dormice, bats, frogs, and numberless other animals of cold blood, which lie torpid and destitute of every sign of life during the winter time; the action of the lungs and of the heart being, if any, imperceptibly weak and languid.

Few, if any animals can exist without a reciprocal succession of sleep and vigilance, and the younger the animal, the greater is its propensity to sleep: the same alternatives seem necessary for the health of several vegetables; a great variety of plants fold up their leaves, and seemingly compose themselves to rest, in the night time,
and

and this disposition for sleep is more remarkable in young plants than in old ones; nor does it, as might be suspected, depend upon the influence of light or heat, since plants in hot houses, where the heat is kept at the same degree, fold up their leaves at a stated time in the evening, and expand them in the morning, whether the light be let in upon them or not. It may deserve to be enquired, whether by a relaxation of fibres these plants become subject to a more copious perspiration during sleep than in their state of vigilance, as Sanctorius hath proved to be the case in animals.

There is a great diversity, but a regular succession in the times, in which animals of different species feel the *œstrum*, by which they are stimulated to the propagation of their respective kinds: an order equally determined, is observable in the times of accomplishing the *sponsalia* of plants. The periods of incubation in oviparous, and of gestation in viviparous animals are not more various in different species, nor probably more definite in the same, than the periods requisite for the germination and maturation of different seeds. By the influence of heat
and

and cold, abundance and scarcity of nourishment, the seasons of propagating may be somewhat accelerated or retarded in animals as well as in vegetables: the effects of a cold ungenial spring are as remarkable in the retardation of the procreative intercourse of birds and beasts, as in the stoppage of the leafing of trees, or the flowering of shrubs. In a word, there are so many circumstances in which the anatomy and physiology of some plants agree with those of some animals, that few, I believe, can be mentioned in which they disagree.

When it is considered that animals are either mediately or immediately wholly nourished from vegetables, it might be expected, a priori, that the products obtainable by a chemical analysis from the two kingdoms should be different rather in quantity than quality, and that we could not from thence discover any criteria by which they might be distinguished from one another: this observation is confirmed by experiment. Animals, it is true, in general yield a greater proportion of a volatile alkaline, than of an acid salt by distillation; vegetables on the contrary abound in acid, and yield not any volatile
alkali,

alkali, unless with the last degree of heat, or when they have undergone putrefaction: in saying this, I am aware that I differ from the opinion commonly received. Mustard seed, water cresses, horse-radish, and other plants of the tetradynamia class are generally said to contain a volatile alkali already formed, and to yield it with the heat of boiling water; from none of these however could I ever obtain B. M. a phlegm which would give a precipitation with corrosive sublimate, the most indubitable test of a fluid's containing even the minutest portion of volatile alkali; the pungent smell seems to have been mistaken here, as Sir John Pringle hath well observed the fœtor to have been in the putrefaction of many animal substances, as proceeding from a volatile alkali; and which may, perhaps, be with greater truth attributed to a volatile oil, a small portion of which is sometimes procurable from pepperwort, by the heat of boiling water impregnated with sea salt. However, as some animals, and some parts of most animals yield a portion of acid, and as most vegetables, by a strong fire in close vessels, or when converted into soot, afford a volatile

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alkali,

alkali, altogether similar to that obtained from animal substances, we cannot from these circumstances establish any distinctive mark between the two kingdoms.

With respect to Minerals indeed, Chemists think that they have found out an infallible and universal Criterion, by which they may be distinguished from every animal or vegetable substance. All bodies from which we can obtain an oil by distillation, or otherwise, are supposed to belong to such substances as have enjoyed an organic life; no mineral, it is said, containing any: this is a sensible distinction, and yet it is not perhaps in extreme cases wholly to be relied upon. When a vegetable or animal is distilled in close vessels, the stronger the fire is, the more oil is obtained; what first passes into the recipient is more clear and limpid than what comes over towards the end of the operation; it may be presumed however, that what remains adherent to the coal in the retort, and which no violence of fire can separate, is not essentially different from the last portions which are distilled; yet this, be it fixed oil or phlogiston, is no wise different from what enters into the composition of
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metallic substances, and of minerals, perhaps, of all kinds. Zinc burns with a flame resembling that of charcoal; lead and tin burn like rotten wood; iron and other metals may be burnt to ashes in the open air, but like charcoal cannot be decomposed in close vessels; spirits of wine burn like sulphur, charcoal and metallic substances without producing any foot; yet from spirits of wine an oil may be obtained: Why should the phlogiston of metals be thought of a nature wholly different from the oil which so obstinately adheres to charcoal, or from that which seems to enter into the composition of vinous spirits?

Naturalists, as well as Chemists, have perhaps too precipitately embraced the opinion, that Minerals may be certainly and readily distinguished from the other two kingdoms. A vascular system, a nutritive fuccus, and a power of producing its like, constitute the abstract idea both of a vegetable and an animal, as contradistinguished from a mineral: this idea is clear and definite in itself; but to determine how far the coexistence of these qualities is in the nature of things necessary, or where any of them ceases to exist, is a question of vast

difficulty when applied to particular cases. Stones dug out of quarries, ores out of mines, in general, minerals separated from their matrices are like the dead branches or limbs of vegetables or animals, incapable of receiving increase, except from an external incrustation; but whether the matrices themselves increase, or that being in some cases granted; whether they receive their augmentation from an external apposition, or an internal assimilation and extension of parts, cannot readily be decided either way. In the Cretan labyrinth it hath been observed, that the names of travellers, which have been cut in the rock in former ages, are now in alto relievo, and that the older the dates are, the greater is the protuberance, resembling the callus formed by incisions in trees: In the mines of Chremnitz in Hungary, which have been wrought for above one thousand years, the antient roads which had been cut through the rocks are left to grow up; and it is remarked, that they approach one another in a horizontal, and not in a perpendicular direction; the same phænomenon may be observed in the marble quarries in Italy, as is mentioned
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by Baglivy in his treatise upon the vegetation of stones; but whether these, and many similar appearances are to be attributed to the pressure of the superincumbent strata, or to a kind of vegetable growth, is a doubtful point. Rock crystals, amethysts, and various precious stones have been thought by De Boot and others to grow like mushrooms; certain it is, that they often contain in them several heterogeneous particles; a circumstance which proves them to have been once in a fluid state, and induces a suspicion that in their formation they may resemble the gums and resins extravasated from various species of vegetables. The vegetation of stones hath been admitted by many, and some have contended that minerals as well as animals and vegetables spring from seed, the greatest rock being nothing but the expansion of the parts of a minute grain of sand.

Salts dissolved in water consist of indefinitely small molecules, which, as far as microscopes can inform us, are similar in figure to the large crystals which become visible to the naked eye, and which are formed, as it were, from the expansion of one particle: it will be easily understood,
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how conformable this mineral crystallization is to the opinion of those, who attribute the growth of animals and vegetables to the accretion of organic particles of the same kind. The concentrick crusts of which stalactites consist, are not either in their appearance, or their formation, perhaps, unlike the circles annually produced by the stagnation of the sap in the boll and branches of trees. The native gold and silver tufts, which appear to burst through the hardest rocks, and which from their great resemblance to trees, have been called by some arborescent, seem to indicate a kind of vegetation in their formation.

Supposing, however, that we pay no attention to any of these circumstances, yet cannot we form any judgement concerning the internal state of the earth. The greatest depths to which Miners have penetrated even in mountainous countries, which may be considered as excrescencies from the true surface of the earth, or the level of the sea, have scarcely ever equalled one sixteen thousandth part of its diameter; a distance altogether insufficient for the forming any probable conjecture about the

the inward constitution of the globe. The strata of stones, and veins of minerals, which are met with upon the surface, can give us as little information concerning the internal structure of the earth from which these are probably derived, as the contemplation of the scales of a fish, the feathers of a bird, or the Epidermis of a man, would concerning the bones and muscles, the veins and arteries, the circulation of the blood, and the several secretions of an animal body. Many minerals seem in their formation to have been antecedent, others subsequent to the universal deluge; a great part of the matter constituting the outward shell of the earth, the only part which we can examine, hath been subservient to vegetable or animal life. All the strata of limestones, chalks, marbles, all gypsums, spars, alabasters, &c. are confessedly of animal origin. The strata of pit-coal, and of all bituminous fossils, of some species of flates, whatever may be thought of argillaceous strata in general, the mould every where covering the surface of the earth, and other substances are supposed probably enough, to have arisen from the destruction of vegetables, so that I know
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not whether it would be a very extravagant conjecture which should suppose that all matter is, or hath been organized, enlivened, animated.

Hence may it appear probable, with reverence yet, and conscious ignorance be it spoken, that the One, Eternal, Incomprehensible God hath established an uninterrupted concatenation in all his works, which he hath submitted to our view. Different individuals hath he mingled together into the same species; different species into the same genus; different genera into the same kingdom; and different kingdoms he hath distinguished, perhaps, but by lines of division too minute for our observation. This strong analogy by which men and minerals, and all intermediate existencies are bound together in a common chain, and thence, it would seem, naturally subjected to a common fate, may appear humiliating to such as have been wont to entertain high notions of the physical dignity of human nature: but it cannot offend nor disquiet those, who feel within themselves faculties essential to the constitution of moral agency, and who from thence become capable at least of retribution

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tribution of punishment or reward in another state.

In the number of our senses, and in the modifications of the intellectual faculties which spring therefrom, we have a great resemblance to many animals which inhabit this planet as well as we. The genus to which man belongs includes a great many subordinate species; or, to speak in a manner more conformable to nature, and more consonant to the account we have of its origin, the human species from the diversities of climate and of food, from changes introduced by disease, and continued, perhaps, by propagation, and from other causes which are unknown to us, hath been branched out into a great many varieties: these, however, are as much distinguished in shape and intellect from one another, as they are from animals which have sprung from a different stock. Anatomists, whether they consider the brain as an instrumental, or an efficient cause of intelligence, are agreed in acknowledging a great resemblance between the contents of the human cranium and those of quadrupeds; and Putius hath proved, contrary to the opinion embraced

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by Pliny, and commonly received, that we have not that medullary substance in a greater proportion than other animals. Nor are we characterised by a circumstance generally esteemed essentially necessary to the support of the human fœtus, and exclusively appertaining to our species: nations are mentioned to whom it doth not belong, and whatever degree of credit may be given to that narration, it is certain that a great many species of animals have been discovered to which it doth. Notwithstanding this analogy by which we are to be classed with the rest of the animals around us, yet hath it pleased Him who called forth from nothing both us and them, and thankful we ought to be for the preference, to place us at the top of the scale, to make us, as it were, the first term of a series, descending indefinitely by imperceptible gradations, to particularize that class of animals to which we belong, by rendering it capable of forming a moral character. This capability, it is true, is various according to the opportunities of, and capacities for receiving instruction in different species, and in different individuals of the same species: the Orang-outang

outang of the woods of Java, the apron-bellied Caffre of the Cape, the woolly-headed Negro of Africa, the beardless Savage of America, the dwarfish Inhabitant of the Frigid Zone, the moon-eyed Albino, and the enlightened European, are as different from one another in this circumstance as in outward form: yet wherever it exists even in the smallest degree, there ariseth a proportionable imputability of conduct, a kind of title to the natural or covenanted good, a reasonable subjection to the natural or positive evil, which God hath annexed as sanctions to the laws which he hath thought fit to prescribe for the regulation of the moral conduct of mankind.





